USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Impact of stream-subsurface exchange on fine sediment dynamics in streams

Focus Categories: SED, G&G, WCL

Keywords: sediment transport, fine suspended sediments, soil erosion, streams, geomorphology, contaminant transport

Duration: 3/99-2/00

Federal Funds Requested: $19,542

Matching Funds Pledged: $44,126

Principal Investigator: Dr. Aaron I. Packman, Drexel University

Congressional District: 2nd District

Statement of critical regional or state water problem

High concentrations of fine sediments adversely impact stream ecosystems by decreasing light penetration through the water column and filling pore spaces in the stream bed. Suburban development leads to increased soil erosion and higher sediment loadings in nearby streams. The geomorphologic characteristics of eastern Pennsylvania coupled with extensive development of rural areas make fine sediment dynamics a key issue for the preservation of streams in this region. Further, the mobility of fine sediments controls the fate and transport of some aqueous contaminants. Most importantly, mine wastes are generally associated with fine sediments-mine tailings are themselves a pollutant, and other contaminants released during mining (metals, arsenic, acidity) interact strongly with sediments. The prevalence of mining and mining-associated water contamination in Pennsylvania also indicates the regional need for an improved understanding of the dynamics of fine sediments in streams.

In spite of these needs, relatively little is known about how fine sediments progress through a watershed. Based on classical sediment transport theory, very fine sediments such as clays are expected to simply progress downstream because they will not settle appreciably in the stream flow. However, new research has indicated that exchange between the stream and subsurface causes fine sediments to be trapped in the stream bed. Though the basic elements of this process are understood, the practical implications for the distribution and impact of high sediment loads have not been explored. Thus this proposal seeks to examine and describe the complex interactions between high sediment loadings, downstream transport of suspended sediment, stream-subsurface exchange, and siltation of stream beds.

Statement of results or benefits

Fine sediment dynamics in streams will be explored through the use of both laboratory and field experiments. A recirculating flume will be used to investigate fine sediment transport in a controlled, easily-observable environment. The sediment loading, stream flow rate, and bed composition will be varied in these experiments. The concentration of sediment in the stream and the changes induced in the stream bed will be observed over time in order to assess both fine sediment dynamics and the impact of fine sediments on the benthic environment. Smaller column experiments will also be used to examine particle capture by the bed sediment. A model developed previously by the PI will be applied to predict the impact of stream-subsurface exchange on downstream suspended sediment transport in the flume. This model will be modified to account for the feedback between accumulation of fine sediments in the bed, reduction in the hydraulic conductivity of bed sediments, and the decrease of stream-subsurface exchange.

Once the basic effect of high sediment loadings is understood, one or more field sites will be established to observe this process in the natural environment. The dynamics of a single reach will be considered-that is, the effect of incoming high sediment loads on a localized section of stream bed will be observed and related to the downstream change in suspended sediment concentration over the reach. The fine sediment transport model will then be used to analyze these data. The successful development and application of this model will provide a tool for the analysis of the impact of high sediment loadings on streams. Such a model could be used to develop guidelines for acceptable sediment loadings for different types of streams, indicate the possible benefit of different release strategies or erosion control measures, and evaluate the potential for recovery of streams that have become loaded with fine sediments. The fine sediment transport model would also be useful to predict the fate and transport of contaminants that associate with these sediments.

Nature, Scope, and Objectives

The purpose of the proposed research is to develop fundamental physical understanding of the basic processes controlling the transport and distribution of fine suspended sediments in streams, especially under high sediment loadings. The primary process that will be studied is the exchange of fine suspended sediments between a flowing stream and the underlying stream bed. Stream-subsurface exchange has recently been identified as an important process, which affects the transport of many stream-borne substances. Understanding the exchange of suspended sediments is especially important because these fine sediments can greatly change the physical characteristics of the stream bed and adversely impact benthic communities. Four key questions must be answered in order to assess the dynamics of fine sediments in streams:

1. What is the rate of uptake of suspended sediment by the stream bed?
2. How does the accumulation of fine sediment affect the hydraulic conductivity, porosity, and other physical characteristics of the bed?

3. How do these changes in the stream bed affect stream-subsurface exchange? That is, what feedback is there between the fine sediment accumulation in the bed and the rate of uptake?
4. What is the net effect on the suspended sediment transport in the stream?

The proposed research will employ several strategies in order to develop an understanding of fine sediment dynamics and apply this knowledge to an impacted stream. Laboratory flume experiments will be used to study exchange processes under carefully controlled conditions. Most importantly, these experiments will allow close examination of the changes in the stream bed due to a continuous input of a high concentration of suspended sediment. Field experiments will be used to study the impact of these processes on a particular stream(s). Fundamental descriptions of individual exchange processes will be developed, and these process descriptions will be integrated into a unified set of models for the downstream transport of fine sediments and the impact of fine sediments on stream beds.